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Space Administration

Mission Highlights STS-90

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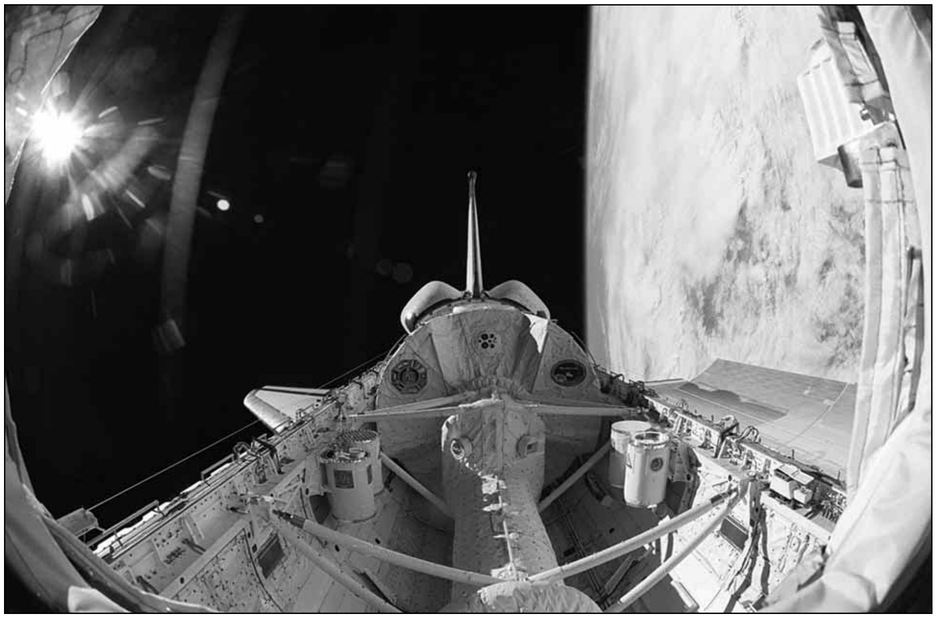
April-May 1998

Neurolab crew brings home gain on brain

Following more than two weeks of on-orbit research designed to gain insight into the human nervous system, the STS-90 crew flying aboard *Columbia* returned to Kennedy Space Center on May 3, 1998. They brought back with them volumes of information gathered from the more than two dozen experiments they performed during the flight.

Mission Specialist Rick Linnehan labeled the Neurolab's principal investigators true heroes for pushing the frontiers of medical science and research for the benefit of society. "Neurolab," he added, "was basic research. We hope to use this information to build on what we've already learned and to improve the quality of human life on the planet. That's what NASA's about."



Out of the window view from *Columbia*'s cabin. The Spacelab Science Module is in frame center. This picture clearly depicts the configuration of the tunnel that leads from the cabin to the module in the center of the cargo bay.

Mission Events

The Shuttle *Columbia* left launch pad 39B at Kennedy Space Center at 1:19 p.m. CDT on April 17, 1998, to begin a 16 day mission to study the human nervous system.

The Neurolab studies included a total of 26 individual experiments, involving both the crew members and crickets, fish and rodents onboard the shuttle. The experiments included studies of blood pressure, balance, coordination, and sleep patterns, and they all have the potential to benefit researchers on Earth studying a variety of illnesses that can affect these functions. They also provided valuable insight into the basic operation of the nervous system, the most complex and least well-known part of the human body. In space, understanding the effects of weightlessness on astronauts is crucial to prepare for long stays.

Space Shuttle *Columbia*

April 17 - May 3, 1998

Commander:	Rick Searfoss
Pilot:	Scott Altman
Mission Specialists:	Rick Linnehan Kay Hire Daffyd (Dave) Williams
Payload Specialists:	Jay Buckey James Pawelczyk

Commander Richard Searfoss at the commander's station on the forward flight deck. The pilot's station is in the foreground.

The *Columbia* swooped to an on-time landing on Runway 33 at the Kennedy Space Center on May 3, 1998, at 11:09 a.m. CDT, bringing to an end the second shuttle mission of the year.

CARGO BAY PAYLOADS NEUROLAB OVERVIEW AUTONOMIC NERVOUS SYSTEM TEAM

The Autonomic Nervous System team investigated the nervous system's control of cardiovascular function in the human body in microgravity. Investigations included measuring blood pressure and blood flow to the brain using the non-invasive transcranial Doppler technique. High frequency sound waves were used to show how blood flow to the brain is regulated.

Other innovative techniques were used on Neurolab, such as microneurography. With this procedure, a small needle is placed in an accessible nerve just below the knee. Nerve signals traveling from the brain to the blood vessels can then be measured directly.

The controlled frequency breathing test allowed for the natural oscillations in the control of blood pressure to be measured. The Valsalva test stimulated the pressure receptors in the neck and chest and measured the responses. The lower body negative pressure test placed a stress on the cardiovascular system very similar to the one experienced when standing in Earth's gravity. The cold pressor and hand grip tests also activated the blood pressure control system and increased blood pressure. Finally, the cuff occlusion test and body impedance measurements showed fluid distribution in the body and how this may contribute to problems in blood pressure control. Evaluations of these tests can localize the part of the autonomic system that may be functioning improperly. Therapy developed from the results of these studies could improve treatment of affected patients here on Earth.

SENSORY MOTOR PERFORMANCE TEAM

The Sensory Motor and Performance Team measured the adaptation of the nervous system to microgravity.

Kinelite System-A Sensory Motor Response Test: In space, this ball catching experiment can tell us if the astronauts adapt rapidly and use vision to compensate for the missing gravity cues, or if they have to take time to relearn this simple task. On Earth, this experiment can be used to study individuals with neurological diseases such as Parkinson's disease, basal ganglia disorders, or cerebellar deficiency. The experiment could also be used for studying motor function development in children. The principal investigator for this experiment was the CNRS/College de France, Paris, France.

Visuo-Motor Coordination during Space Flight: This experiment noted changes in the eye-hand coordination of astronauts during adaptation to microgravity. New methods for programming the movements of robots were generated during the development of the VCF experiment. These methods could eventually improve the capacity of robots to perform complex tasks. Experiment results can also help the development of new methods for evaluating a patient's ability to use visual and pressure cues. The principal investigator for this experiment was Deutsche Sporthochschule, Koeln, Germany.

Role of Visual Cues in Spatial Orientation

The study looks at how astronauts use vision, the vestibular organs of the inner ear, and pressure cues to determine where they are and what they are looking at while in space. Portable head-mounted virtual reality displays, such as the one developed for this Neurolab experiment, can be useful by providing visual prostheses for individuals with vestibular impairment. Study results can help in the design of flight simulator and virtual reality vision systems. The principal investigator for this experiment was the Massachusetts Institute of Technology, Cambridge, MA.

VESTIBULAR TEAM

Clinical tests of inner ear functions often measure eye movements in only two directions: up-down and right-left. The eye movement system, developed for Neurolab by the European Space Agency, allows for measuring eye movements in all directions, allowing for more sensitive tests of inner ear performance. Experiment results may also contribute to the design of more effective rehabilitation procedures for patients with severe inner ear diseases.

SLEEP TEAM

The Neurolab sleep studies are expected to help individuals with a high incidence of insomnia, such as shift workers, the elderly, and people traveling across time zones. The sleep studies have also resulted in technical advancements. A new portable system for recording sleep and respiration during space flight has been developed for the Neurolab mission that allows sophisticated sleep studies to be performed at home, rather than in hospital diagnostic sleep laboratories.

MAMMALIAN DEVELOPMENT TEAM

The Neurolab mammalian development experiments expand the knowledge of the critical period for developing normal vision to the control of movement, regulation of blood pressure and maintaining balance. Information from these studies can be applied to the development of treatments for individuals suffering from childhood neuromuscular diseases, such as muscular dystrophy, or from sustained trauma to their nerves, muscles or spinal cord.

Neuro-Thyroid Interaction on Skeletal Isomyosin Expression in 0 g: This experiment used developing rats to examine the interactive role of gravity and thyroid hormone in the production of special muscle proteins called myosin. Exposure to the space environment leads to muscle atrophy (wasting) similar to that seen during prolonged periods of bed rest or during certain diseases.

Better understanding of how gravity impacts important developmental and maturation processes in muscles could provide insights that could prevent muscle wasting for bed ridden patients or lead to treatments of muscle wasting diseases on Earth. The principal investigator for this experiment was the University of California College of Medicine at Irvine.

Neuronal Development Under Conditions of Space Flight: This experiment was designed to determine whether the sensory information provided by gravity after birth is necessary for the development of spatial ability. Spatial ability is the ability to know where we are in relation to our environment. This investigation provided insights into early brain development. An enhanced understanding of early brain development is crucial to providing infants and children an environment which allows the brain to attain its maximum capacity. Applications to pressing medical conditions are also expected because spatial ability is frequently affected in a variety of brain diseases, including Alzheimer's disease and stroke. The principal investigator for this experiment was the Brigham and Women's Hospital, Boston, MA.

Reduced Gravity: Effects in the Developing Nervous System: Proliferation of nerve cells through a well-choreographed series of "birthdays" and subsequent cell migrations is a necessary process for normal brain development. Experiment E093 will study this process in space to determine if gravity is required for normal brain development. The principal investigator for this experiment was the University of Medicine and Dentistry of New York.

Microgravity and Development of Vestibular Circuits: This experiment determined if exposure to gravity is a required form of stimulation for development of normal structure and function of the vestibular system. The vestibular system is responsible for helping animals and people maintain their balance. Information obtained from this study provided greater understanding of how the vestibular system adapts to changing environments. This may be particularly beneficial for learning how to treat patients on Earth whose vestibular system may be damaged due to illness or injury. The principal investigator for this experiment was the University de Montpellier II, Montpellier, France.

Effects of Microgravity on Neuromuscular Development: This experiment examined if there is a critical period when gravity is required for the normal development of muscles in young rats. Results from this study have strong implications for rearing normal animals, including humans, in the microgravity environment of space, and will further our understanding of the importance of weight bearing activity for motor system development of human infants on Earth. Premature infants, living in incubators, are deprived of exercising their legs against the uterine wall, and infants may have diseases that limit normal weight bearing activity. The studies of neonatal rats provide valuable insights into the role of gravity in the development process, and if appropriate, may indicate exercise procedures to promote normal development in compromised infants. The principal investigator for this experiment was the Medical College of Wisconsin, Milwaukee, WI.

NEURONAL PLASTICITY TEAM

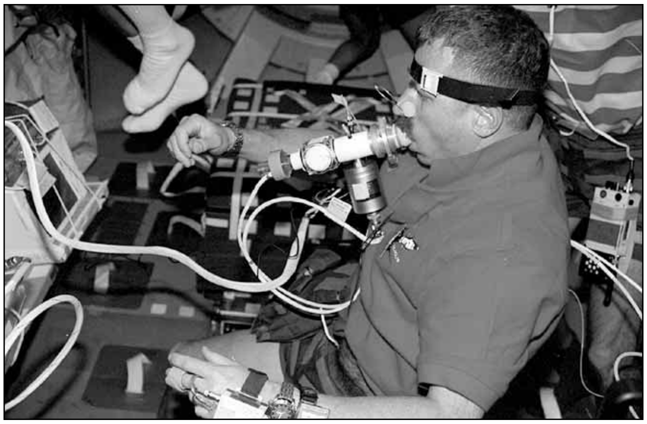
Experiments on vestibular adaptation yield a better understanding of balance disorders, which affect more than 90 million Americans. Experiments on circadian rhythms could yield valuable data to researchers seeking the causes of jet lag, insomnia and mental disorders, such as winter depression. This data is also applicable to aging populations and shift workers, both of whom experience changes in circadian rhythms.

Rhythms and Homeostasis during Space Flight: The goal of this experiment was to determine how space flight affects the timing and intensity of circadian rhythms of body temperature, heart rate, and activity in rats exposed to different light cycles. The effects of space flight on the neurons in the brain that make up the circadian clock were also observed by measuring immediate early gene (IEG) activation in response to light/dark stimuli. IEGs, a newly discovered class of intracellular messengers that contain instructions for the production of proteins, come in several forms. Experiments leading to greater understanding of circadian rhythms could help researchers seeking the causes of jet lag, insomnia and mental disorders, such as winter depression. The principal investigator for this experiment was the University of California, Davis, CA.

Anatomical Studies of Central Vestibular Adaptation: This experiment identified the structural and chemical changes that occur in the cerebellum as a result of adaptation to microgravity and re-adaptation to Earth's gravity. The cerebellum is the part of the brain that is critical for maintaining balance and for processing information from the limbs so that they may be moved smoothly. Approximately 12.5 million Americans over the age of 65 are afflicted by balance disorders, including vertigo and dizziness. Data from this study may provide increased understanding of the causes of balance disorders which, in turn, could lead to possible remedies. The principal investigator for this experiment was the Mount Sinai School of Medicine, New York, NY.

Multidisciplinary Studies of Neural Plasticity in Space: This experiment employed a number of modern methods to obtain information on how space flight affects the structure and function of the neurovestibular system, particularly the gravity-sensing organs in the inner ear. The computer software developed by the investigator to help analyze data from space has found widespread application beyond the field of neuroscience. For example, the investigator is currently working with the Department of Reconstructive Surgery at Stanford University to produce an interactive, collaborative virtual environment for planning of craniofacial surgeries. The

Astronaut Kathryn Hire participates in a sensory motor and performance test. Astronaut Dave Williams monitors the experiment.



Astronaut Dave Williams is pictured during a Neurolab pulmonary function test.

principal investigator for this experiment was the NASA Ames Research Center, Moffett Field, CA.

AQUATIC TEAM

Data from the aquatic experiments on Neurolab may disclose the mechanisms at work in various forms of motion sickness experienced by many people on Earth. The studies may also help explain why aging otoliths become smaller. Further benefits include the use and perfection of the sieve or wafer electrode that is used to record nerve impulses. This electrode offers potential use as a connection to the nervous system in people with deafness caused by hair cell damage. It also could be used as an interface to signal motor prostheses how and when to move.

Chronic Recording of Otolith Nerves in Microgravity: This investigation used Oyster Toadfish to determine if the otolith organs, which sense gravity and body position, experience plasticity. By recording data from the nerves of the inner ears of fish, the investigator should be able to understand the changes in the same signals sent by the astronauts' inner ears as they adapt to microgravity. This information could shed light on the causes of space motion sickness experienced by astronauts and motion sickness experienced on Earth. The wafer electrode technology used in this experiment may have clinical applications for patients suffering from nerve disorders or injuries. The principal investigator for this experiment was the Washington University School of Medicine, Saint Louis, MO.

Development of Vestibular Organs in Microgravity: These studies offer new insight into the mechanisms controlling otolith formation and maintenance. Recent studies indicate that calcium loss from the otoliths may contribute to balance problems in elderly humans. Falls, which can be quite harmful to older individuals, are a common side effect of balance problems. The principal investigator for this experiment was the University of Texas Health Science Center at San Antonio, San Antonio, TX.

NEUROBIOLOGY TEAM

The Neurobiology team provided information on the relative importance of the environment and other external stimuli (like gravity) on nervous system development. The gravity system of crickets serves as a model to investigate the general effects of altered gravitational conditions on the development of the structure, function and efficiency of a gravity sensory system. Insects offer useful model systems because their central neurons can be easily identified.

Get Away Specials

G-197: The primary objectives of this experiment were to demonstrate the pulse tube cooling technology in the zero gravity environment of space, and to gain operational experience with the smallest such cryocooler yet built. Pulse Tube refrigerators, or cryocoolers, can be used to cool infrared sensors and other devices to approximately minus 315 degrees Fahrenheit. Very cold sensors are used in space based research and are needed to study the temperature variations in the atmosphere and oceans to aid in the understanding of the ozone hole, global warming, and long range weather forecasting.

G-772: Students at the University of Colorado, Boulder, CO, designed a payload that analyzed the gentle collisions of dust particles in space, which may shed new light on the sources of dust in planetary rings. The principal investigator for this payload was from the University of Colorado at Boulder.

G-744: The objective of this experiment, from Sierra College in Rocklin, CA, is to take ozone measurements of the Earth's upper atmosphere in the ultraviolet 200 nanometer to 400 nanometer spectral range using a Charge Coupled Device based spectrometer. A Charge Coupled Device camera also flew as part of the experiment and provided target verification for the spectrometer. The principal investigator is Sierra College.

IN CABIN PAYLOADS

Shuttle Vibration Forces: The Shuttle Vibration Forces (SVF) experiment measured the dynamic forces acting between the Space Shuttle and a canister attached to the Shuttle sidewall. In previous Shuttle flights, the vibration motion at various positions in the cargo bay has been measured, but the SVF experiment will provide the very first measurements of the dynamic forces acting on Shuttle equipment. The SVF data, together with a new vibration testing method, will enable NASA to fly more sophisticated equipment on the Shuttle, at less cost. The principal investigator for SVF is located at the Jet Propulsion Laboratory, Pasadena, CA. The mission is located at Goddard Space Flight Center in Greenbelt, MD.

BIOREACTOR DEMONSTRATION SYSTEM - 04

The Bioreactor Demonstration System-04/ Biotechnology Specimen Temperature Controller is a reconfigurable, multichamber, temperature-controlled, static tissue culture apparatus. The BDS system on STS-90 housed two experiments:

Human Renal Cell experiment: This experiment evaluated renal cells in their differentiation or maturity of function, the production of erythropoietin (EPO) and the production of 1-25-diOH Vitamin D3. EPO and Vitamin D3 are two very important renal hormones, which are given to patients with diseases such as kidney disease, AIDS, Cancer chemotherapy patients, and other diseases of immune function. Any improvement in the production of these hormones will advance the ability to treat numerous diseases in the U.S. and the world.

The Microgravity Induced Differentiation of HL-60 Promyelocytic Leukemia cells: This experiment studied the differentiation (maturation) of bone marrow like cells, which have the ability to become a myriad of immune cells found in the human physiology. Immune cells, which mature from the original cells, can be found in the blood, bone marrow and immune system, and are responsible for fighting disease. These types of cells often need to be replaced in patients which have undergone chemotherapy, radiation therapy, or have experienced diseases of the immune system. An understanding of how these cells are formed is critical to development of new strategies for combating disease.

CREW BIOGRAPHIES

Commander: Richard A. Searfoss (Lt. Col., USAF, Col. Selectee). Searfoss, 41, was born in Mount Clemens, MI, but considers Portsmouth, NH, to be his hometown. He received a bachelor of science degree in aeronautical engineering from the USAF Academy, and a master of science degree in aeronautics from the California Institute of Technology on a National Science Foundation Fellowship.

Searfoss became an astronaut in 1991, and was the pilot on STS-58 and STS-76. STS-58 was a seven-person life science research mission on which the crew performed neurovestibular, cardiovascular, cardiopulmonary, metabolic, and musculoskeletal medical experiments on themselves and 48 rats, expanding our knowledge of human and animal physiology both on Earth and in space flight.

During the nine-day STS-76 mission the crew performed the third docking of an American spacecraft with the Russian space station Mir. In support of a joint U.S./Russian program, the crew transported to Mir nearly two tons of water, food, supplies, and scientific equipment, as well as U.S. astronaut Shannon Lucid to begin her six-month stay in space. STS-76 included the first ever spacewalk on a combined space shuttle-space station complex. The flight crew also conducted scientific investigations, including European Space Agency sponsored biology experiments, the Kidsat Earth observations project, and several engineering flight tests. With the completion of STS-90, Searfoss has logged more than 939 hours in space.

Pilot: Scott D. Altman (Lt. CDR., USN). Altman, 38, was born in Lincoln, IL. He received a bachelor of science degree in aeronautical and astronautical engineering from the University of Illinois, and a master of science degree in aeronautical engineering from the Naval Postgraduate School.

Altman was commissioned an Ensign in the United States Navy following completion of Aviation Reserve Officer Candidate School in Pensacola, FL. Following training in Florida and Texas, he received his Navy wings of gold and was ordered to NAS Miramar in San Diego, CA, to fly the F-14. Attached to Fighter Squadron 51, Altman completed two deployments to the Western Pacific and Indian Ocean. He was selected for the Naval Postgraduate School-Test Pilot School Coop program and graduated with Test Pilot School Class 97 as a Distinguished Graduate. After graduation, he spent the next two years as a test pilot working on various F-14 projects. Altman was awarded the Navy Air Medal for his role as a strike leader flying over Southern Iraq in support of Operation SOUTHERN WATCH.

Altman became an astronaut in 1995, and with the completion of STS-90 had logged more than 382 hours of space flight.

Payload Commander: Richard M. Linnehan (DVM). Linnehan, 40, was born in Lowell, MA. He received a bachelor of science degree in animal sciences with a minor in microbiology from the University of New Hampshire and the degree of Doctor of Veterinary Medicine from the Ohio State University College of Veterinary Medicine.

Linnehan became an astronaut in 1992, and previous to STS-90 flew on STS-78. STS-78 served as a model for future studies onboard the International Space Station. The Life Sciences and Microgravity Spacelab mission included studies sponsored by ten nations and five space agencies. The international crew included 5 Americans, a Frenchman, a Canadian, a Spaniard, and an Italian. With the completion of STS-90, Linnehan has logged over 787 hours in space.

Mission Specialist: Kathryn P. (Kay) Hire (CDR., U.S. Naval Reserve). Hire, 37, was born in Mobile, AL. She received a bachelor of science degree in engineering and management from the U.S. Naval Academy, and a master of science degree in space technology from Florida Institute of Technology.

Hire began work at the Kennedy Space Center in May 1989, first as an Orbiter Processing Facility 3 Activation Engineer with EG&G, and later as a Space Shuttle Orbiter Mechanical Systems Engineer for Lockheed Space Operations Company. In 1991, she certified as a Space Shuttle Test Project Engineer (TPE). From the TPE computer console position in the Launch Control Center, she integrated all technical aspects of space shuttle turnaround maintenance from landing through the next launch. Additionally, she headed the checkout of the Extravehicular Mobility Units (space suits) and Russian Orbiter Docking System. Hire was assigned Supervisor of Space Shuttle Orbiter Mechanisms and Launch Pad Swing Arms in 1994. Hire became an astronaut in 1995, and with the completion of STS-90 has accumulated more than 382 hours of space flight.

On-orbit portrait: From left (with feet toward floor) Scott Altman, Richard Searfoss, and Richard Linnehan. Others, from left, Kathryn Hire, Jay Buckey, Jim Pawelczyk and Dave Williams.

STS-90
Quick Look

Launch Date: April 17, 1998
Time: 1:19 p.m. CDT
Site: KSC Pad 39B

Orbiter: *Columbia*
OV-102—25th flight

Orbit/In.: 150 naut. miles
39 degrees

Mission Duration: 15 days, 21 hrs, 50 mns.

Landing Date: May 3, 1998
Time: 11:09 a.m. CDT
Site: Kennedy Space Center

Crew: Rick Searfoss (CDR)
Scott Altman (PLT)
Rick Linnehan (MS1)
Kay Hire (MS2)
Daffyd (Dave) Williams (MS3)
Jay Buckey (PS1)
James Pawelczyk (PS2)

Cargo Bay Payloads: Neurolab, Get Away Specials

In-Cabin Payloads: Bioreactor Demo Test-04, Shuttle Vibrations Forces

Mission Specialist: Daffyd (Dave) Rhys Williams (MD). Williams, 43, was born in Saskatoon, Saskatchewan. He received a bachelor of science degree in biology from McGill University, Montreal, a master of science degree in physiology and a doctorate of medicine and a master of surgery from McGill University, Montreal, in 1983. He completed residency in Family Practice in the Faculty of Medicine, University of Ottawa, and obtained Fellowship in Emergency Medicine from the Royal College of Physicians and Surgeons of Canada, following completion of a Residency in Emergency Medicine at the University of Toronto.

Williams was selected by the Canadian Space Agency and, after completion of basic training, was appointed Manager of the Missions and Space Medicine Group within the Astronaut Program. His collateral duty assignments have included supervising the implementation of Operational Space Medicine activities within the Astronaut Program, and the coordination of the Canadian Astronaut Program Space Unit Life Simulation Project.

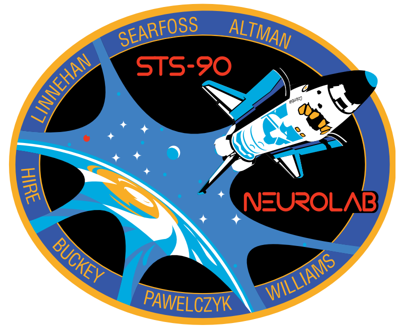
In 1995, Williams was selected to join the 1995 international class of NASA mission specialist astronaut candidates, and became an astronaut in 1996. After completion of STS-90, he has accumulated more than 382 hours of space flight.

Payload Specialist: Jay Clark Buckey, Jr. (MD). Buckey, 41, was born in New York, NY. He received a bachelor of science degree in electrical engineering from Cornell University, and a doctorate in medicine from Cornell University Medical College. He interned at New York Hospital-Cornell Medical Center, and completed residency at Dartmouth-Hitchcock Medical Center. He was a NASA Space Biology Fellow at the University of Texas (UT) Southwestern Medical Center.

For NASA, Buckey was a co-investigator and project manager for the space flight experiment “Cardiovascular Adaptation to Zero-Gravity,” Spacelab Life Sciences-1; and an alternate payload specialist for the Spacelab Life Sciences-2 mission. With the completion of STS-90, he has accumulated more than 382 hours in space.

Payload Specialist: James A. (Jim) Pawelczyk (Ph.D.). Pawelczyk, 37, was born in Buffalo, NY. He received two bachelor of arts degrees in biology and psychology from the University of Rochester, NY; a master of science degree in physiology from the Pennsylvania State University; and a doctor of philosophy degree in biology (physiology) from the University of North Texas. He completed a post-doctoral fellowship at the University of Texas Southwestern Medical Center.

Pawelczyk took leave from Penn State University, where he was an Assistant Professor of Physiology and Kinesiology, to train as a payload specialist for STS-90 (Neurolab). For NASA, Pawelczyk was a member of the user design group, GASMAP (Gas Analysis System for Metabolic Analysis Physiology), and a unit principal investigator for the NASA Specialized Center for Outreach, Research and Training (NSCORT) grant in integrative physiology. He received a NASA Young Investigator Award for his work in the area of autonomic neurophysiology. With the completion of STS-90, Pawelczyk has accumulated more than 382 hours of space flight.



The STS-90 crew patch reflects the dedication of the mission to the neurosciences in celebration of the Decade of the Brain. The Earth is revealed through a neuron-shaped window, which symbolizes new perspectives in the understanding of nervous system development, structure and function, both here on Earth and in the microgravity environment of space.

The Orbiter *Columbia* is depicted with its open payload bay doors revealing the Spacelab within. An integral component of the mission, the laboratory provided by the European Space Agency signifies the strong international involvement in the mission.

The seven crew members and two alternate payload specialists are represented by the nine major stars of the constellation Cetus (the whale) in recognition of the International Year of the Ocean. The distant stars illustrate the far reaching implications of the mission science to the many sponsoring agencies, helping prepare for long-duration space flight aboard the International Space Station.

The Moon and Mars will be the next great challenges in human exploration of space, and represent the key role that life science research will play in supporting such missions.